AD

AD-E402 635

Technical Report ARFSD-TR-94031

COIL AND STRAP ASSEMBLY INDUCTANCE TEST

Hegel G. Neira

April 1995

US ARMY
TANK AUTOMOTIVE AND
ARMAMENTS COMMAND
ARMAMENT RDE CENTER

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Fire Support Armaments Center

Picatinny Arsenal, New Jersey

REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operation and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 1995	3. REPORT TYPE AND DATES COVERED Annual/Oct 92 to Oct 93	
4. TITLE AND SUBTITLE COIL AND STRAP ASSEMBLY INDUCTANCE TEST		5. FUNDING NUMBERS	
6. AUTHOR(S) Hegel G. Neira			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSES(S) ARDEC, FSAC Precision Munitions/Mine and Demolitions Division (AMSTA-AR-FSP) Picatinny Arsenal, NJ 07806-5000		8. PERFORMING ORGANIZATION REPORT NUMBER	
9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S) ARDEC, IMD Information Research Center (AMSTA-AR-IMC) Picatinny Arsenal, NJ 07806-5000		10. SPONSORING/MONITORING AGENCY REPORT NUMBER Technical Report ARFSD-TR-94031	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE	

13. ABSTRACT (Maximum 200 words)

This technical report is an evaluation of the engineering methods applied in establishing electrical parameters for key components of the Volcano Mine Dispenser System, as well as the instrumentation used to measure these parameters. One such component in the Volcano system is the magnetic coupling device, which is basically an inductor, or a coil, that plays a particularly important role, of crucial importance in the system's electrical mine/dispenser interface; by setting the self destruct times of the mines, during mine deployment.

Electrical parameters had to be established after an investigative team deemed it necessary to have an inductance test added to the assembly procedures of the M87 Volcano canister. This added test will detect shorts in individual coils of the coil and strap assembly which would render all mines in the canister to be duds. It will also detect opens in the individual coils as well as grossly misaligned coils. Both these conditions will cause only the individual mines to dud.

The test and measurement techniques used as well as the engineering equations, on which decisions were based, will be reexamined along with reevaluation of the data gathered and instrumentation used. The safety concerns resulting from this issue will also be addressed.

14. SUBJECT TERMS Inductance Volcano canister Magnetic coupling device Coil and strap assembly			15. NUMBER OF PAGES 27 16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR

NSN 7540-01 280-5500
Prescribed by ANSI Std. Z39-18
298-102

Standard Form 298 (Rev. 2-89)

CONTENTS

INTRODUCTION

Like bullets used in a gun, mines are used in mine dispenser system, not to shoot at a target, but to lay minefields. But unlike guns, a mine dispenser system is also required to impart the arming signal and the self-destruct (SD) times to each mine at the time of mine dispensing.

The Volcano mine dispenser system[1] and the mine that it uses (the Gator mine, slightly modified to become the Volcano mine) were developed and manufactured separately, but are subsequently assembled into one integral system.

The Volcano mine dispenser system mainly consists of a dispenser control unit (DCU), a launcher rack, the hand control unit (HCU), and the M87 canister which contains the stack of mines to be deployed. The electronic mine interface is located inside the canister, and will be the focus of this report.

Following the establishing of the inductance test, the instrumentation to be used became an issue because it was determined that not all parties involved in the manufacturing of the M87 Volcano canister had the same type of inductance meters. The Lone Star Army Ammunition Plant (LSAAP) had an inductance meter which they intended to use for the proposed inductance test that employs a different technique for reading inductance values. This meter is a different type than the meter used by the Iowa Army Ammunition Plant (IAAP) and the producer of the coil and strap assembly. The meter that LSAAP used, although of the standard off-the-shelf type, differed from the other in that it made use of an alternate basic electrical engineering equation to measure the inductance value of the transmitter coils. These equations, on which the two inductance meters based their design, will be discussed along with the data taken that was later used to justify their approval.

BACKGROUND

As a result of a red team investigation that reviewed the tests performed on the M87 Volcano canister, an inductance test was established to complement the direct current (DC) continuity test. This test was determined to be inadequate since it did not detect opens or shorts in the individual coils of the coil and strap assembly (fig. 1). An open will only result in an individual mine being a dud; but, a short will result in the entire stack (six mines) dudding. The inductance test will provide the capability to detect short or opens in individual coils; in addition, it will also give the added benefit of detecting grossly misaligned coils which can also result in individual mines dudding.

[1]Neira, Hegel G., "The Volcano Mine Dispenser System," February 1993.

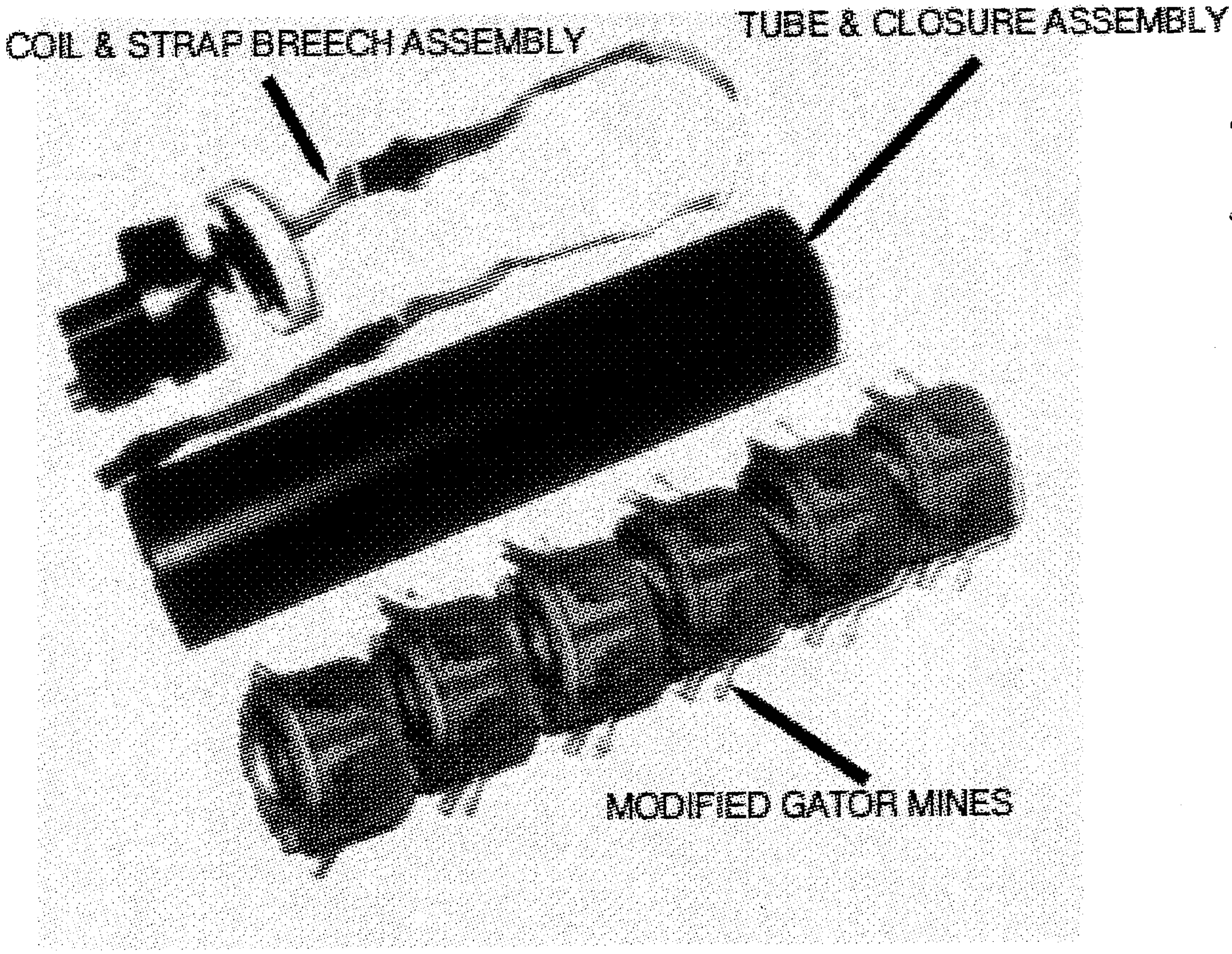


Figure 1
Volcano mine canister assembly

The new inductance test was to be performed on the assembled M87 Volcano canister, but because it contained live mines, safety issues were raised by IAAP personnel in a preproduction meeting concerning the approval of an engineering change that made the inductance test a requirement, . The proposed M87 canister inductance test safety concerns were in reference to the energy levels of the signals generated during actual inductance measurement or testing. Iowa AAP inquired if it was possible that the energy levels generated during testing would be sufficient to initiate the electronic battery initiators (EBI) inside the mines, thus initiating the safe and arming (S&A) mechanism of the mines endangering the safety of production personnel. Therefore, the signals generated during the inductance measurement and testing had to be limited to less than the no-fire electrical threshold of the EBIs.

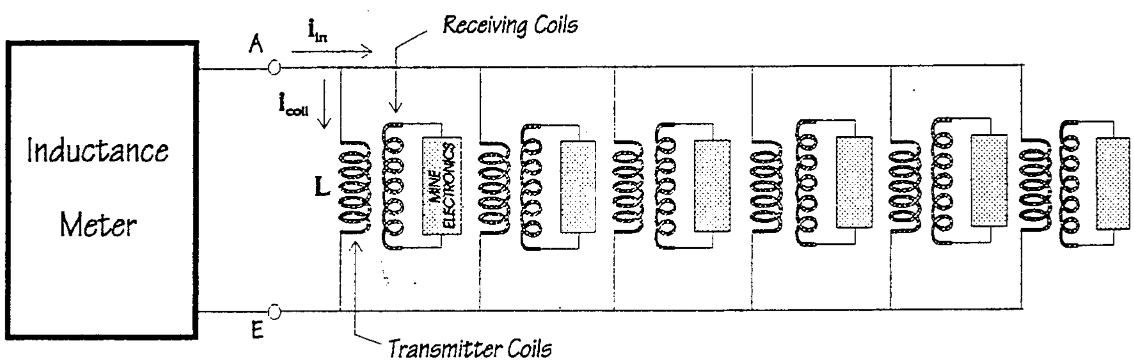
Keeping this in mind, the technical discussions that follow will show that safety indeed was the main concern. Engineering methods along with statistical inference were the sole basis for achieving a truly representative value for the magentic coupling device (MCD), or transmitter coil, inductance.

TECHNICAL DISCUSSION

The technical and safety issues relating to the proposed inductance test mainly involve the following assemblies and subassemblies of the M87 Volcano canister:

- Breech assembly
  - S&A
  - Propulsion system
- Electronic mine interface
  - Coil and strap assembly

Although the proposed inductance test will be performed on the test points A and E that are on the canister connector (at the back of the Breech assembly), they have no connection with the propulsion system or the Volcano Canister's S&A. Figure 2 is a schematic of the inductance test circuit.



L

Figure 2
Inductance test schematic

The transmitter coil assembly specification[2] calls for the value of each inductor to be 19.5 ± 2.0 µH at 10 KHz. Inspection of the this circuit gives a total inductance value at test points A and E of:

$$L_{total\ (parallel)} = L/6 = 19.5/6 = 3.25\ \mu H$$

This circuit will be used to calculate the generated power that is used when performing the inductance test with each of the proposed inductance meters.

Coil and Strap Assembly

The coil and strap assembly is basically composed of six MCDs or transmitter coils in parallel, covered by a nylon strap neatly packed inside the M87 canister tube assembly. It is 66 in. long and has the function of relaying the proper signals from the DCU to the mines to activate the mine's batteries and internally set their SD times.

When the coil and strap assembly is assembled inside the Volcano canister and the inductance test is performed, the input signals generated during this test would have to be, as stated before, well below the no-fire threshold of the EBI, which according to the EBI specification[3], is 10 mA maximum for a 10 sec duration. Using the minimum resistance of 1.0 Ω from the same specification, the power (P) can be calculated as follows:

$$P = i^2R = (10 \times 10^{-3})^2 (1) = 0.1 \text{ mW}$$

Therefore, it follows that the energy levels generated during the inductance test would have to be below 0.1 mW. The lower the generated power, the higher the margin of safety.

The energy levels generated by the inductance meters themselves during actual inductive tests, indicate the inductance value of the assembly. When a signal (of known characteristics) is applied to the part under test, the returned signal (processed electronically) is based on mathematical formulas or equations as shall be shown later.

With this in mind, the energy levels generated by each inductance meter will be calculated from their own specifications.

Inductance Meters

An inductor is a device for storing energy in a magnetic field. It is sometimes regarded as the magnetic counterpart of a capacitor, which stores energy in an electric field. To measure the inductance value of inductors, two types of inductance meters were developed and are readily available on the market today. Both of these meters

---

[2]Drawing 9378619.

[3]Drawing 9292624 of the Volcano mine dispenser's technical data package.

are based on the notion of electrokinetic momentum[4] that defines electricity flowing through an inductor in a circuit as Li, which is the product of the current, and a characteristic of the circuit called inductance. Analogous to Newton's second law[5] of mechanics, a derivation of the expression Li gives the following:

$$v = d/dt(Li)$$

for constant inductance

$$v = L\,di/dt \tag{1}$$

Now, if a sinusoidally alternating current is assumed as the input

$$\begin{aligned} v &= L\,d/dt\,(I_m \cos \omega t) \\ &= -\omega L I_m \sin \omega t \end{aligned}$$

applying a trigonometric identity to this equation gives

$$v = \omega L I_m \cos(\omega t + \pi/2)$$

which at its maximum gives

$$v_m = \omega L I_m \tag{2}$$

Where V_m and I_m are the maximum sinusoidally alternating voltage and current, respectively, and the term ωL is called inductive reactance. Also, $\omega = 2\pi f$, where f is the frequency of the applied signal measured in Hertz.

In the first equation, for a given voltage, the change in current value (usually a ramp of constant slope) with respect to time is monitored by the inductance meter, and the unit under test assigned a value accordingly.

In the second equation, the inductance value is calculated with respect to frequency for set voltage and current values.

---

[4]Electrical property analogous to mechanical momentum (mv) discovered by J. Henry in the 1830s working at Princeton, and some years later defined with the symbol λ by clerk Maxwell.

[5]$F = d/dt(mv)=m(dv/dt)=ma$.

These well known electrical engineering equations (eqs 1 and 2) are the basis of the two most commonly available inductance meters in the market today. An inductance meter made by Hewlett Packard (HP), Model 4284A, is based on the second equation and used by the coil and strap assembly supplier (New Bedford Components) and at IAAP for their inductance tests. On the other hand, the second type of inductance meter, the LC Sencore 102, based on the first equation, is now being used at LSAAP's loading plant assembly line for their tests. The supplier adheres to the technical data package (TDP)[6], while the LSAAP cites ease of use in the assembly line, as well as programmability, for their selection.

To accommodate all parties, while at he same time addressing the pertinent safety issues, the following analysis and measurements were conducted.

Electronic Mine Interface

Six Volcano mines are stacked inside the M87 Volcano canister tube, one on top another separated by the coil and strap assembly which serves as the mine/dispenser interface (fig. 1). An electrical schematic of the interface is shown in figure 3 for one of the six mines inside the canister.

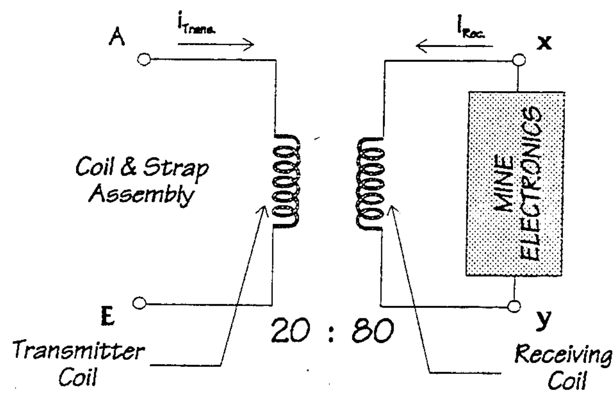


Figure 3
Electrical interface schematic

Each of the transmitter coils of the coil and strap assembly faces the MCD of a Volcano mine (fig. 3). According to the TDP, the number of turns (N) of the windings on the transmitter side is 20, and 80 on the receiving side.

[6]It call for testing to be performed with respect to frequency (10 KHz).

At the time of inductance testing, a signal is applied by the inductance meter to the coil and strap assembly (the transmitting side) which induces a signal on the EBI (receiving side), with a required energy level of less than 0.1 mW.

Assuming ideal coupling and using the following formulas

$$N_1/N_2 = V_1/V_2 = I_2/I_1$$

where the subscript 1 and 2 denote transmitting and receiving, respectively.

Knowing that the HP 4284A provides a test signal of 10 mV and 100 μA at 10 KHz, the value of the signal that the receiving side sees, due to the applied signal at the transmitter's side can be calculated using formulas

$$V_2 = V_1\,(N_2/N_1) \tag{3}$$

and

$$I_2 = I_1\,(N_1/N_2) \tag{4}$$

using equation 3 gives

$$\begin{aligned} V_2 &= 10\text{ mV }(80/20) \\ &= 40\text{ mV} \end{aligned}$$

Now, using equation 4, and from figure 2 it follows that

$$I_{Coil} = I_1 = I_{in}/6$$

gives

$$I_1 = 100\ \mu\text{A}/6 = 16.67\ \mu\text{A}$$

which follows that

$$\begin{aligned} I_2 &= 16.67\ \mu\text{A }(20/80) \\ &= 4.167\ \mu\text{A} \end{aligned}$$

This means that the energy levels seen at the receiving side are 40 mV and 4.167 μA. This further translates into a power input at the receiving side of

$$\begin{aligned} P_{Rec.} &= I_2V_2 = (4.167\ \mu\text{A})\ (40\text{ mV}) \\ &= 0.167\ \mu\text{W} \end{aligned}$$

As calculated before, this is well below the 0.1 mW of no-fire energy specified for the EBI.

A similar analysis conducted for the LC 102 Sencore inductance meter, which inputs a signal of 50 mA and 0.1 mV into the unit under test, yields the following results

$$I_1 = 50\ \text{mA}/6 = 8.33\ \text{mA}$$
$$I_2 = 8.33\ \text{mA}\ (20/80)$$
$$= 2.083\ \text{mA}$$

and

$$V_2 = 0.1\ \text{mV}\ (80/20)$$
$$= 0.4\ \text{mV}$$

These results also translate into an input power at the receiving side of

$$P_{Rec.} = I_2V_2 = (2.083\ \text{mA})(0.4\ \text{mV})$$
$$= 0.8332\ \mu\text{W}$$

Which, again is well below the no-fire requirement of 0.1 mW for the EBI.

Establishing a New Inductance Value

Once the safety concerns were satisfied, a discrepancy between the inductance readings obtained with each of the inductance meters had to be resolved, and it was accomplished in the following manner.

A random sample of 32 coil and strap assemblies was picked and each assembly numbered. Next, inductance measurements were made using both types of meters (table 1). The LC 102 readings were taken at LSAAP and the HP 4284A readings at ARDEC.

As can be seen at first glance in table 1 and by reviewing the inductance test results graph that follows table 1, the LC 102 meter measurements always produced a much lower value than the values obtained with the HP 4284A meter, averaging a difference of 0.47 μH. in the inductance readings, or about an 18% difference in value.

The inductance readings, obtained using the two different test methods, consistently gave different values, as can be seen in the coil and strap assembly data in table 1 and on the inductance test results graph (fig. 4).

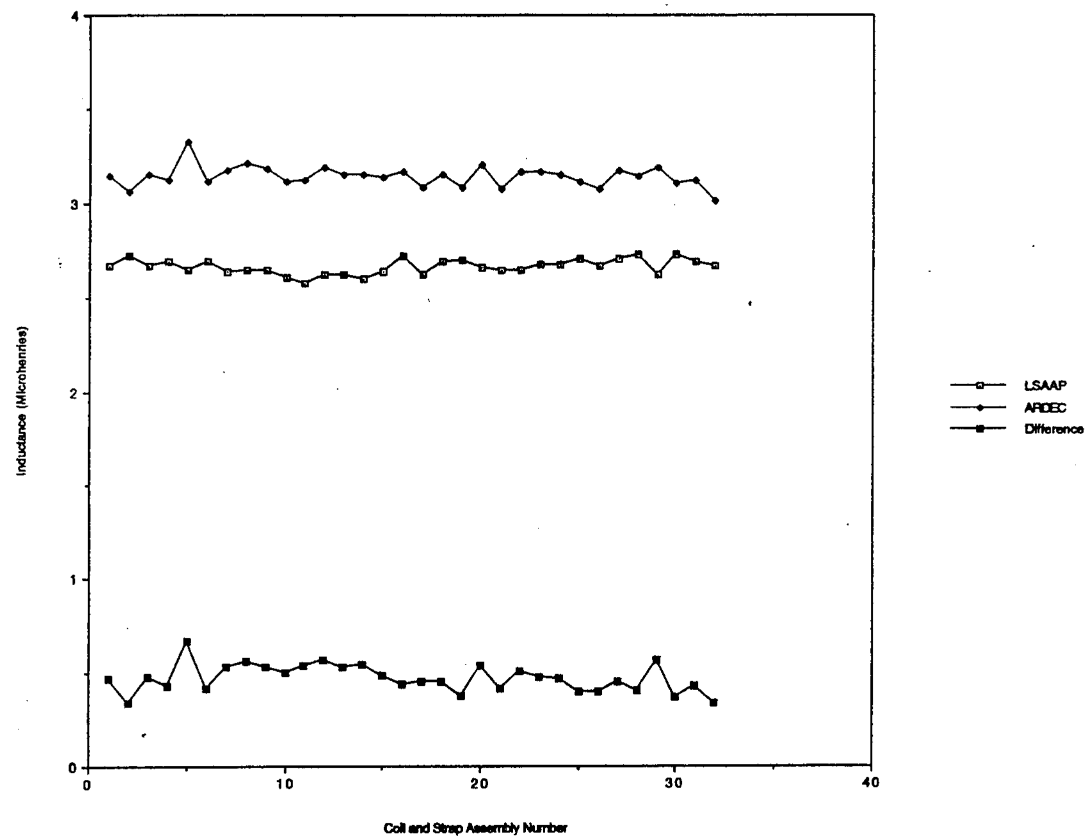


Figure 4
Inductance test results

These preliminary tests indicated that a statistical analysis along with sound engineering judgment, was required to provide an acceptable solution.

To conduct a statistical analysis, a large data base had to be established. Inductance tests performed at LSAAP as well as at the IAAP loading plant provided this base. Tests were conducted in almost every conceivable arrangement, and because the tests were performed on loaded canisters, when the coil and strap assembly coils are facing the receiving coils of the Volcano mines (fig. 3) a parallel coupling effect was observed that affected the final outcome of the inductance reading. As was demonstrated with exhaustive testing, the coupling effect practically cut the expected inductance value in half.

It was also determined that the degree of alignment between the receiving and transmitting coils would affect the outcome; therefore, a simulated misalignment test was conducted in the lab by taping receiving coils to the coil and strap assembly and making measurements (table 2) with the first to the sixth coils misaligned at different times; as well as the first and sixth, the first and the third and the fifth misaligned at the same time. A similar amount of testing was also performed with different arrangements of coils which were purposely shorted to see the effect.

After testing the lab arrangement, the M87 Volcano canister itself was tested. It was found out that the weight and pressure of the mines and loading pressures exerted on the coil and strap assembly interface created a tighter coupling, and the resulting inductance value was lower.

After the inductance readings began to be consistent, only one thing remained to be done; that is to support the findings with data. Approximately 700 canisters were tested (app A) at LSAAP using the LC 102 Sencore meter which used equation 1. With this data, and using a normal distribution, a statistical analysis of the data yielded a final value of $1.05 \pm 0.35\ \mu H$.

An identical amount of testing performed at the IAAP loading plant (app B) with the second type of inductance meter, that uses equation 2, or the HP 4284A, resulted in establishing a value for the inductance reading using this meter of $1.55 \pm 0.40\ \mu$ at 10 KHz.

It should be pointed out that these tests also detected shorted coils in the canister, as can be seen in appendix A (sample 56 on 3-2-93, sample 95 on 3-3-93, and sample 104 on 3-4-93), as well as detecting misaligned coils as can be seen in appendix B (sample 70).

In effect, two measuring methods were devised to accommodate each facility while at the same time assuring proper inductance values for the electronic mine interface.

CONCLUSIONS

The circuit analysis conclusively ruled out the possibility that any of the safety concerns raised earlier could ever be encountered. It was also shown that the energy levels of the signals are well below those needed to activate the electronic battery initiators. As a matter of fact, they are several orders of magnitude below the minimum no-fire value.

With regard to establishing a new inductance value, it was established by empirical methods, that is to say, the results were based on experiment.

The inductance values measured through contacts A and E on the back of the M87 Volcano canister connector are now established for two testing methods. One is with the use of an inductance meter based on equation 2 for which a value of 1.55 $\pm$ 0.40 μH at 10 KHz with an input of 100 μA (max) and 10 mV (max) should be obtained, and the second method with the use of equation 1 for which a value of 1.05 $\pm$ 0.35 μH should be obtained if a ramp current input of 50 mA/μsec is applied.

As was verified during inductance testing, the primary purpose of the inductance test was confirmed. This test, to be performed on all canisters from now on, will detect shorted as well as grossly misaligned coils on the assembly line well before the fielding stage.

The time and effort that was put into the coil and strap assembly inductance testing, which led to a reduced dud rate, is more than justified because of these reasons.

Table 1
Coil and strap assembly data

	A	B	C	D
1	ASSY #	LSAAP	ARDEC	DIFFERENCE
2	1	2.67	3.14	0.47
3	2	2.72	3.06	0.34
4	3	2.67	3.15	0.48
5	4	2.69	3.12	0.43
6	5	2.65	3.32	0.67
7	6	2.69	3.11	0.42
8	7	2.64	3.17	0.53
9	8	2.65	3.21	0.56
10	9	2.65	3.18	0.53
11	10	2.61	3.11	0.5
12	11	2.58	3.12	0.54
13	12	2.62	3.19	0.57
14	13	2.62	3.15	0.53
15	14	2.60	3.15	0.55
16	15	2.64	3.13	0.49
17	16	2.72	3.16	0.44
18	17	2.62	3.08	0.46
19	18	2.69	3.15	0.46
20	19	2.70	3.08	0.38
21	20	2.66	3.20	0.54
22	21	2.65	3.07	0.42
23	22	2.65	3.16	0.51
24	23	2.68	3.16	0.48
25	24	2.68	3.15	0.47
26	25	2.71	3.11	0.4
27	26	2.67	3.07	0.4
28	27	2.71	3.17	0.46
29	28	2.73	3.14	0.41
30	29	2.62	3.19	0.57
31	30	2.73	3.10	0.37
32	31	2.69	3.12	0.43
33	32	2.67	3.01	0.34
34				
35				
36				
37	AVERAGES:	2.67	3.14	
38	MAX:	2.73	3.32	
39	MIN:	2.58	3.01	

Table 2
Lone Star Army Ammunition Plant inductance-shorted

Array #	Norm. w/ SW	1 Mis w/ SW	2 Mis w/ SW	3 Mis w/ SW	4 Mis. w/ SW	5 Mis w/ SW	6 Mis w/ SW	1st SH. w/ SW	6t SH. w/ SW	1&6 SH. w/ SW	1,3,5 SH. SW		
1	1.47	1.54	1.69	1.76	1.81	1.93	1.81	0.47	0.46				
2	1.4	1.53	1.55	1.8	1.8	1.86	1.94	0.58	0.58	0.54	0.48		
3	1.36	1.44	1.49	1.65	1.56	1.67	1.66	0.32	0.34	0.25	0.2		
4	1.47	1.65	1.57	1.63	1.82	1.94	1.97	0.45	0.47	0.42	0.35		
5	1.5	1.55	1.6	1.64	1.71	1.66	1.83	0.42	0.4	0.33	0.36		
6	1.44	1.55	1.65	1.71	1.83	1.83	1.9	0.42	0.44	0.36	0.33		
7	1.39	1.44	1.48	1.55	1.62	1.69	1.72	0.41	0.41	0.34	0.32		
8	1.41	1.48	1.5	1.54	1.6	1.68	1.73	0.42	0.43	0.36	0.35		
9	1.37	1.47	1.55	1.63	1.7	1.78	1.91	0.39	0.4	0.31	0.31		
10	1.46	1.5	1.56	1.56	1.57	1.63	1.64	0.38	0.29	0.32	0.16		
11	1.53	1.59	1.64	1.6	1.64	1.67	1.8	0.41	0.41	0.35	0.34		
12	1.57	1.61	1.64	1.66	1.71	1.8	1.86	0.43	0.45	0.38	0.36		
13	1.48	1.56	1.61	1.57	1.61	1.65	1.78	0.38	0.38	0.31	0.29		
14	1.32	1.33	1.38	1.59	1.63	1.69	1.74	0.24	0.39	0.27	0.18		
15	1.46	1.58	1.56	1.59	1.6	1.66	1.74	0.4	0.45	0.35	0.36		
16	1.48	1.68	1.73	1.75	1.81	1.88	1.87	0.38	0.43	0.35	0.39		
17	1.41	1.6	1.63	1.64	1.7	1.7	1.75	0.3	0.31	0.25	0.24		
18	1.39	1.58	1.61	1.66	1.7	1.74	1.82	0.38	0.38	0.31	0.28		
19	1.56	1.74	1.76	1.77	1.78	1.81	1.86	0.49	0.52	0.44	0.41		
20	1.33	1.5	1.72	1.71	1.75	1.78	1.82	0.49	0.5	0.39	0.4		
21	1.33	1.4	1.47	1.49	1.51	1.58	1.6	0.32	0.32	0.26	0.25		
22	1.34	1.39	1.39	1.42	1.5	1.54	1.57	0.3	0.28	0.22	0.23		
23	1.47	1.62	1.58	1.62	1.67	1.64	1.66	0.4	0.4	0.34	0.33		
24	1.45	1.65	1.6	1.62	1.68	1.71	1.76	0.4	0.42	0.35	0.35		
25	1.44	1.48	1.52	1.53	1.57	1.63	1.65	0.42	0.44	0.37	0.37		
26	1.4	1.42	1.44	1.47	1.55	1.57	1.59	0.29	0.24	0.22	0.21		
27	1.27	1.34	1.41	1.41	1.5	1.55	1.55	0.29	0.3	0.22	0.21		
28	1.38	1.47	1.53	1.55	1.63	1.61	1.72	0.38	0.37	0.28	0.33		
29	1.25	1.28	1.37	1.43	1.49	1.58	1.6	0.24	0.26	0.18	0.18		
30	1.27	1.29	1.35	1.37	1.41	1.45	1.46	0.19	0.19	0.11	0.11		
31	1.36	1.38	1.42	1.45	1.51	1.52	1.55	0.33	0.33	0.27	0.25		
32	1.38	1.52	1.51	1.54	1.59	1.65	1.67	0.33	0.32	0.24	0.24		
33	1.43	1.51	1.52	1.55	1.57	1.59	1.8	0.42	0.39	0.33	0.31		
34	1.49	1.48	1.54	1.58	1.64	1.71	1.72	0.41	0.37	0.35	0.31		
Min	1.25	1.28	1.35	1.37	1.41	1.45	1.46	0.19	0.19	0.11	0.11		
Max	1.57	1.74	1.76	1.77	1.83	1.94	1.97	0.58	0.58	0.54	0.48		
Mean	1.413529412	1.500882353	1.545588235	1.583529412	1.640294118	1.687058824	1.730882353	0.378823529	0.383823529	0.314242424	0.296060606		
Std. Dev.	0.079004501	0.108050708	0.105405189	0.100298018	0.108819912	0.117358023	0.125489771	0.079420809	0.082792721	0.081356864	0.083626379		
Upper 3-sig	1.650542916	1.825034476	1.861803741	1.884426466	1.967053854	2.039132892	2.107351667	0.617085956	0.632201891	0.558313018	0.546939742		
Lower 3-sig	1.176515908	1.17673023	1.22937273	1.282632357	1.313534382	1.334984755	1.354413039	0.140561103	0.135445368	0.070171831	0.04518147		

APPENDIX A

VOLCANO CANISTER ASSEMBLY
INDUCTANCE READING A - E

VOLCANO CANISTER ASSY. INDUCTANCE READING A-E

APPENDIX A

DATE: 3-1-93

SAMPLE NUMBER	INDUCTANCE READING (µh)	SAMPLE NUMBER	INDUCTANCE READING (µh)	SAMPLE NUMBER	INDUCTANCE READING (µh)	SAMPLE NUMBER	INDUCTANCE READING (µh)
1	0.89	51	0.95	101	1.05	151	0.95
2	0.88	52	0.96	102	1.08	152	0.87
3	0.85	53	1.02	103	0.94	153	0.87
4	0.88	54	0.88	104	1.01	154	0.91
5	0.95	55	0.97	105	0.98	155	0.93
6	0.85	56	0.97	106	0.98	156	0.88
7	0.84	57	0.91	107	0.97	157	0.96
8	0.73	58	1.01	108	1.08	158	0.86
9	0.84	59	0.95	109	1.00	159	0.99
10	0.83	60	1.05	110	0.97	160	0.93
11	0.87	61	0.93	111	1.09	161	0.96
12	0.99	62	0.94	112	0.95	162	1.04
13	1.04	63	1.04	113	0.98	163	1.02
14	0.99	64	0.98	114	1.00	164	0.97
15	1.01	65	1.03	115	0.94	165	1.05
16	1.07	66	1.08	116	0.92	166	1.01
17	1.00	67	1.00	117	1.00	167	0.96
18	1.12	68	1.00	118	1.03	168	1.00
19	1.04	69	0.98	119	1.03	169	1.00
20	1.02	70	0.91	120	0.99	170	1.07
[illegible]	0.98	71	0.84	121	0.99	171	1.06
22	1.04	72	0.85	122	1.00	172	1.04
23	1.04	73	1.02	123	1.00	173	1.07
24	1.03	74	0.96	124	0.95	174	0.93
25	1.02	75	1.06	125	1.00	175	0.94
26	1.05	76	1.04	126	1.03	176	0.95
27	0.92	77	1.04	127	0.94	177	0.94
28	0.86	78	1.10	128	0.94	178	0.98
29	0.84	79	0.90	129	1.01	179	1.02
30	0.82	80	0.87	130	0.99	180	0.97
31	0.82	81	0.90	131	1.00	181	0.89
32	0.98 sample	82	0.91	132	1.00	182	0.95
33	0.98	83	1.06	133	1.05 sample	183	0.96
34	1.00	84	1.14	134	1.10	184	
35	1.02	85	1.09	135	0.98	185	
36	1.02	86	1.11	136	1.02	186	
37	1.00	87	1.08	137	1.02	187	
38	1.00	88	1.13	138	1.02	188	
39	0.98	89	1.10	139	1.08	189	
40	1.02	90	1.11	140	1.06	190	
41	1.05	91	1.07	141	1.07	191	
42	0.96	92	1.10	142	1.11	192	
43	0.88	93	1.03	143	1.00	193	
44	0.89	94	0.97	144	1.00	194	
45	0.84	95	0.95	145	0.90	195	
[illegible]	0.90	96	0.87	146	1.04	196	
[illegible]	0.88	97	0.88	147	0.96	197	
48	0.91	98	0.93	148	0.96	198	
49	1.02	99	1.07	149	0.96	199	
50	1.02	100	1.14	150	0.84	200	

VOLCANO CANISTER ASSY.
INDUCTANCE READING A-E

DATE 3-2-93

SAMPLE NUMBER	INDUCTANCE READING µh	SAMPLE NUMBER	INDUCTANCE READING µh	SAMPLE NUMBER	INDUCTANCE READING µh	SAMPLE NUMBER	INDUCTANCE READING µh
1	1.26	51	1.07	101	0.95	151	1.07
2	1.15	52	0.93	102	0.86	152	1.03
3	1.19	53	0.16	103	0.86	153	0.90
4	1.27	54	0.89	104	0.83	154	0.93
5	1.19	55	0.89	105	0.88	155	0.96
6	1.26	56	0.09	106	0.91	156	0.75
7	1.16	57	.87	107	0.82	157	0.95
8	1.21	58	.91	108	0.89	158	0.90
9	1.17	59	.89	109	0.99	159	1.06
10	1.22	60	.92	110	0.99	160	0.93
11	1.15	61	.92	111	0.95	161	1.02
12	1.12	62	.91	112	0.97	162	1.10
13	1.12	63	.89	113	0.95	163	1.06
14	1.14	64	0.89	114	0.90	164	1.05
15	.87	65	1.08	115	0.91	165	1.08
16	1.15	66	1.06	116	0.96	166	1.02
17	1.15	67	0.59	117	0.92	167	1.01
18	1.12	68	0.96	118	0.97	168	0.99
19	1.10	69	0.88	119	1.01	169	1.05
20	10.6	70	1.15	120	1.00	170	100.3
[illegible]	1.16	71	1.07	121	1.05	171	0.98
22	1.12	72	1.03	122	1.06	172	0.97
23	1.20	73	0.96	123	1.04	173	1.01
24	1.10	74	1.04	124	0.94	174	0.94
25	1.11	75	1.00	125	0.99	175	0.97
26	1.19	76	0.94	126	0.97	176	1.06
27	1.09	77	0.86	127	1.01	177	0.97
28	1.10	78	0.89	128	0.59	178	1.08
29	1.14	79	0.94	129	1.00	179	0.98
30	1.16	80	0.94	130	0.86	180	1.11
31	1.03	81	1.01	131	0.91	181	1.10
32	1.00	82	0.93	132	0.93	182	1.16
33	.94	83	0.99	133	1.00	183	1.16
34	.93	84	0.96	134	0.99	184	1.08
35	.85	85 Sample	0.93	135	0.97	185	0.96
36	.86	86	0.98	136	0.96	186	
37	.98	87	1.02	137	0.96	187	
38	.82	88	0.89	138	0.95	188	
39	1.00	89	1.01	139	0.90	189	
40	1.05	90	0.90	140	0.94	190	
41	1.03	91	1.04	141	0.92	191	
42	1.10	92	1.03	142	0.93	192	
43	1.06	93	1.05	143	0.94	193	
44	1.06	94	1.18	144	0.95	194	
45	1.15	95	1.11	145	0.94	195	
[illegible]	1.10	96	1.01	146	0.93	196	
[illegible]	.96	97	0.95	147	0.95	197	
48	1.05	98	1.01	148	0.99	198	
49	1.10	99	0.90	149	1.07	199	
50	1.00	100	1.01	150	1.06	200	

VOTCAND CANISTER ASSY.
INDUCTANCE READING A-E

DATE: 3-13-93

SAMPLE NUMBER	INDUCTANCE READING µh	SAMPLE NUMBER	INDUCTANCE READING µh	SAMPLE NUMBER	INDUCTANCE READING µh	SAMPLE NUMBER	INDUCTANCE READING µh
1	1.09	51	1.06	101	1.05	151	1.02
2	1.05	52	1.09	102	1.03	152	.98
3	1.04	53	1.19	103	1.03	153	1.02
4	1.05	54	1.17	104	1.04	154	1.01
5	1.04	55	1.13	105	1.04	155	1.03
6	1.11	56	1.08	106	1.06	156	1.04
7	1.10	57	1.09	107	1.01	157	1.07
8	1.15	58	1.08	108	1.01	158	1.05
9	1.15	59	.95	109	1.07	159	1.06
10	1.12	60	1.09	110	1.04	160	1.07
11	.96	61	.96	111	1.13	161	1.03
12	1.00	62	1.13	112 SAMPLE #8	1.07	162	1.10
13	.97	63	1.09	113	1.08	163	1.11
14	1.02	64	1.14	114	1.04	164	1.13
15	1.04	65	1.13	115	1.06	165	1.09
16	1.11	66	1.08	116	1.05	166	1.07
17	1.09	67	1.05	117	1.13	167	1.06
18	1.05	68	1.03	118	1.10	168	1.05
19	1.09	69	1.05	119	.94	169	1.06
20	1.12	70	1.07	120	.97	170	1.06
[illegible]	1.16	71	1.04	121	.96	171	1.08
22	1.17	72	1.05	122	.97	172	1.09
23	1.16	73	1.08	123	1.15	173	.98
24	1.17	74	1.09	124	1.10	174	1.00
25	1.13	75	1.13	125	1.10	175	.99
26	1.13	76	1.02	126	1.12	176	1.02
27	1.10	77	1.00	127	1.15	177	1.04
28	1.10	78	1.02	128	1.13	178	1.05
29	1.08	79	1.02	129	.72	179	1.06
30	1.05	80	1.05	130	1.13	180	1.02
31	1.14	81	1.07	131	1.08	181	1.00
32	1.16	82	1.08	132	1.08	182	.99
33	1.14	83	1.05	133	1.07	183	1.06
34	1.11	84	1.08	134	1.09	184	1.01
35	1.09	85	1.11	135	1.12	185	1.02
36	1.09	86	1.07	136	1.12	186	1.04
37	1.13	87	1.04	137	1.11	187	1.08
38	1.11	88	1.06	138	1.13	188	1.07
39	1.10	89	1.03	139	1.09	189	1.06
40	1.10	90	1.07	140	1.08	190	1.00
41	1.15	91	1.09	141	1.03	191	1.06
42	1.08	92	1.13	142	1.02	192	1.00
43	1.06	93	1.03	143	1.07	193	.
44	1.11	94	1.06	144	1.09	194	.
45	1.08	95	.38	145	1.12	195	.
46	1.09	96	1.05	146	1.06	196	.
[illegible]	1.11	97	1.06	147	1.07	197	.
48	1.10	98	1.04	148	1.13	198	.
49	1.08	99	1.08	149	1.07	199	.
50	1.08	100	1.07	150	1.04	200	.

VOLCANO CANISTER ASSY.
INDUCTANCE READING A-E

DATE: 3-4-93 LS 93B005-009

SAMPLE NUMBER	INDUCTANCE READING μh	SAMPLE NUMBER	INDUCTANCE READING μh	SAMPLE NUMBER	INDUCTANCE READING μh	SAMPLE NUMBER	INDUCTANCE READING μh
1	1.09	51	1.06	101	.94	151	.
2	1.11	52	1.04	102	1.04	152	.
3	1.09	53	1.08	103	1.01	153	.
4	1.13	54	1.10	104	.30	154	.
5	1.11	55	1.14	105	.98	155	.
6	1.19	56	1.14	106	.95	156	.
7	1.01	57	1.10	107	1.00	157	.
8	1.12	58	1.00	108	1.03	158	.
9	1.09	59	1.05	109	1.08	159	.
10	1.09	60	1.05	110	.92	160	.
11	1.07	61	.93	111	1.06	161	.
12	1.05	62	.94	112	.99	162	.
13	1.09	63	.93	113	.98	163	.
14	1.12	64	.98	114	.94	164	.
15	1.15	65	1.00	115	.99	165	.
16	1.13	66	.93	116	1.05	166	.
17	1.07	67	.96	117	1.05	167	.
18	1.05	68	1.00	118	1.05	168	.
19	1.06	69	.97	119	.94	169	.
20	1.09	70	.94	120	.98	170	.
21	1.07	71	1.08	121	1.01	171	.
22	1.11	72	1.05	122	.93	172	.
23	1.14	73	1.12	123	.90	173	.
24	1.12	74	1.06	124	.94	174	.
25	1.12	75	1.04	125	.98	175	.
26	1.12	76	1.08	126	1.00	176	.
27	1.00	77	.95	127	1.08	177	.
28	1.10	78	.91	128	1.01	178	.
29	1.06	79	.92	129	.95	179	.
30	1.03	80	.94	130	.94	180	.
31	1.12	81	1.00	131	.96	181	.
32	1.09	82	1.01	132	.95	182	.
33	1.07	83	1.00	133	.91	183	.
34	1.12	84 49 sample	1.01	134	.91	184	.
35	1.11	85	.96	135	.94	185	.
36	1.14	86	.99	136	1.01	186	.
37	1.05	87	.97	137	.97	187	.
38	1.08	88	.98	138	.92	188	.
39	1.11	89	.97	139	.95	189	.
40	1.14	90	1.00	140	.93	190	.
41	1.08	91	.99	141	.	191	.
42	1.08	92	1.02	142	.	192	.
43	1.10	93	1.00	143	.	193	.
44	1.16	94	1.01	144	.	194	.
45	1.16	95	.98	145	.	195	.
46	1.16	96	.92	146	.	196	.
47	1.11	97	.98	147	.	197	.
48	1.07	98	.98	148	.	198	.
49	1.03	99	.93	149	.	199	.
50	1.04	100	.93	150	.	200	.

APPENDIX B

VOLCANO, LOT NUMBER 1OP93E001--002
FINAL CANISTER INDUCTANCE READINGS

03-Jun-93

MASON & HANGER – SILAS MASON CO., INC.

APPENDIX B

VOLCANO
LOT NUMBER IOP93E001–002
FINAL CANISTER INDUCTANCE READINGS

#	READING	#	READING	#	READING	#	READING	#	READING
1	1.46	51	1.65	101	1.40	151	1.41	201	1.40
2	1.58	52	1.64	102	1.69	152	1.73	202	1.43
3	1.57	53	1.85	103	1.87	153	1.43	203	1.42
4	1.42	54	1.91	104	1.38	154	1.44	204	1.49
5	1.48	55	1.63	105	1.60	155	1.54	205	1.42
6	1.47	56	1.85	106	1.39	156	1.43	206	1.43
7	1.41	57	1.63	107	1.53	157	1.47	207	1.46
8	1.43	58	1.86	108	1.40	158	1.43	208	1.65
9	1.62	59	1.81	109	1.33	159	1.41	209	1.36
10	1.35	60	1.69	110	1.54	160	1.55	210	1.42
11	1.47	61	1.55	111	1.40	161	1.55	211	1.40
12	1.55	62	1.53	112	1.38	162	1.60	212	1.46
13	1.43	63	1.63	113	1.38	163	1.39	213	1.43
14	1.45	64	1.72	114	1.42	164	1.40	214	1.42
15	1.52	65	1.64	115	1.44	165	1.50	215	1.43
16	1.43	66	1.61	116	1.54	166	1.40	216	1.41
17	1.35	67	1.66	117	1.46	167	1.40	217	1.49
18	1.34	68	1.60	118	1.94	168	1.46	218	1.41
19	1.49	69	1.62	119	1.65	169	1.51	219	1.40
20	1.61	70	2.30	120	1.67	170	1.39	220	1.47
21	1.46	71	1.55	121	1.40	171	1.39	221	1.54
22	1.36	72	1.57	122	1.50	172	1.42	222	1.38
23	1.65	73	1.54	123	1.78	173	1.37	223	1.71
24	1.71	74	1.55	124	1.51	174	1.46	224	1.50
25	1.42	75	1.58	125	1.55	175	1.58	225	1.66
26	1.64	76	1.55	126	1.41	176	1.56	226	1.44
27	1.42	77	1.68	127	1.75	177	1.42	227	1.44
28	1.67	78	1.71	128	1.36	178	1.48	228	1.43
29	1.58	79	1.55	129	1.61	179	1.46	229	1.55
30	1.65	80	1.67	130	1.39	180	1.41	230	1.54
31	1.77	81	1.67	131	1.42	181	1.46	231	1.40
32	1.55	82	1.59	132	1.54	182	1.44	232	1.36
33	1.57	83	1.64	133	1.46	183	1.63	233	1.36
34	1.63	84	1.89	134	1.46	184	1.35	234	1.39
35	1.68	85	1.62	135	1.38	185	1.47	235	1.39
36	1.66	86	1.57	136	1.56	186	1.54	236	1.49
37	1.47	87	1.67	137	1.44	187	1.37	237	1.38
38	1.59	88	1.57	138	1.43	188	1.44	238	1.41
39	1.75	89	1.61	139	1.38	189	1.37	239	1.44
40	1.56	90	1.63	140	1.41	190	1.41	240	1.40
41	1.68	91	1.67	141	1.44	191	1.38	241	1.37
42	1.72	92	1.76	142	1.50	192	1.40	242	1.46
43	1.62	93	1.52	143	1.36	193	1.41	243	1.47
44	1.77	94	1.63	144	1.44	194	1.44	244	1.38
45	1.62	95	1.58	145	1.39	195	1.49		
46	1.71	96	1.70	146	1.36	196	1.43		
47	1.59	97	1.68	147	1.66	197	1.42		
48	1.71	98	1.73	148	1.74	198	1.38		
49	1.58	99	1.77	149	1.43	199	1.40		
50	1.58	100	1.45	150	1.41	200	1.48		

AVERAGE OF READINGS	1.526107
MINIMUM READING	1.33
MAXIMUM READING	2.3
STANDARD DEVIATION	0.137231

$\frac{1}{244} > 1.95$

Final Range

$\boxed{1.15 \text{ to } 1.95\ \mu H}$

Dave Ling →

IOWA ARMY AMMUNITION PLANT: VOLCANO INDUCTANCE

LOT: IOP93G001-005 DATA COLLECTED FOR APPROXIMATELY ONE SHIFT

REFERENCE: NOR M3N3009 APPROVED 930617, SMCAR-FSP-E
SINUSOIDAL INPUT, 1.55 +/- 0.40 uH

1.95

TEST SAMPLES 1 - 5 X-RAYED

1-5 high inductance

1/2" mis-alignment

uH INDUCTANCE

SAMPLE	PRIOR TO CRIMP	AFTER CRIMP	PRIOR - AFTER
1	2.163	2.048	-0.115
2	2.237	2.095	-0.142
3	2.194	2.006	-0.188
4	2.381	2.157	-0.224
5	2.201	2.189	-0.012
6	2.346	2.298	-0.048
7	2.038	1.972	-0.066
8	2.139	1.984	-0.155
9	2.227	1.988	-0.239
10	2.138	1.991	-0.147
11	2.294	2.233	-0.061
12	2.209	2.041	-0.168
13	2.104	1.987	-0.117
14	2.044	1.953	-0.091
15	2.115	2.071	-0.044
16	2.610	2.612	0.002
17	2.215	1.971	-0.244
18	2.215	2.012	-0.203
19	2.144	2.114	-0.030
20	2.108	2.070	-0.038
21	1.988	1.954	-0.034
22	2.030	2.040	0.010
23	2.222	2.194	-0.028
24	2.240	2.149	-0.091
25	2.077	2.027	-0.050

X-RAY CONTROL

1A	*	1.666	*
2A	*	1.852	*

GENERAL OBSERVATIONS

1. ALIGNMENT OF COILS IS OFF IN DIRECTION O THE STRAP.
2. ALIGNMENT DIS-PLACEMENT INCREASE AS THE TUBE WAS MOVED TO THE MINE NEXT TO THE BREECH.

Post-It™ brand fax transmittal memo 7671 | # of pages ▸ 1

To JOHN PRINTZ	From KEN GOERING
Co. ARDEC	Co. MASON & HANGER
Dept. SMCAR-FSP-E	Phone # DSN-585-7038
Fax # DSN 880-5931	Fax # DSN 585-7113

- Same lot of C & D Cases UBP91G002-102. (same lot that has been used).
- Operator dependence.

* DATA WAS NOT RECORDED

- roughly 30 out of 125 per day.
- lots 3 + 4 appeared ok. (600) + (1720).

SUMMARY FOR OVER 1.95 uH

AVG PRIOR TO CRIMP	2.1872	
AVG AFTER CRIMP	2.0862	
AVG DROP IN uH	-0.1009	<=== AFTER CRIMP
TEST STD DEVIATION	0.1439	"
3 SIGMA HIGH AFTER CRIMP	2.5179	"

2254

KEN GOERING, PRODUCTION ENGINEERING, DSN 585-7038, 28 JUL 93

DISTRIBUTION LIST

Commander
Armament Research, Development and Engineering Center
U.S. Army Tank-automative and Armaments Command
ATTN: AMSTA-AR-IMC (3)
AMSTA-AR-GCL
AMSTA-AR-FSP (6)
Picatinny Arsenal, NJ 07806-5000

Administrator
Defense Technical Information Center
ATTN: Accessions Division (12)
Cameron Station
Alexandria, VA 22304-6145

Director
U.S. Army Materiel Systems Analysis Activity
ATTN: AMXSY-MP
Aberdeen Proving Ground, MD 21005-5066

Commander
Chemical/Biological Defense Agency
U.S. Army Armament, Munitions and Chemical Command
ATTN: AMSCB-CII, Library
Aberdeen Proving Ground, MD 21010-5423

Director
U.S. Army Edgewood Research, Development and Engineering Center
ATTN: SCBRD-RTB (Aerodynamics Technology Team)
Aberdeen Proving Ground, MD 21010-5423

Director
U.S. Army Research Laboratory
ATTN: AMSRL-OP-CI-B, Technical Library
Aberdeen Proving Ground, MD 21005-5066

Chief
Benet Weapons Laboratory, CCAC
Armament Research, Development and Engineering Center
U.S. Army Armament, Munitions and Chemical Command
ATTN: SMCAR-CCB-TL
Watervliet, NY 12189-5000

Director
U.S. Army TRADOC Analysis Command-WSMR
ATTN: ATRC-WSS-R
White Sands Missile Range, NM 88002